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Abstract

A method to determine the effective source size for a Monte Carlo model of a robotic radiosurgery system

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Abstract

Objectives: The Monte Carlo (MC) dose calculation algorithm is particularly important for stereotactic body radiotherapy (SBRT) of sites in or near the lung. The MC algorithm implemented in the CyberKnife treatment planning system (TPS) uses a single source model to determine the photon phase space. The three components of the source model are determined from measured beam data. The target distribution may also be modeled with a Gaussian function determined by a user-specified value of the effective source size. The Gaussian method overall produces accurate penumbra width in the calculated beam profiles, although there is a single source size for all collimator sizes. Currently there is no quantitative method to guide the user in selecting the optimal effective source size and the user selects the source size by trial-and-error based on manually comparing the penumbra width in the calculated and measured OCR for all the collimators. We present a quantitative method for choosing the optimum effective source size.

Methods: The biggest effect of a model with an incorrect effective source size will be either an increase or a decrease in the sharpness of the penumbra. We calculated the error in the penumbra region of the profile between the model prediction and measured data for a range of source sizes and fit a quadratic to find the source size that minimized this error. We defined the penumbra as the region between 10% and 90% of the dose on central axis. The error was calculated for each collimator size at depths of 15, 50, 100, 200, and 300 mm, by taking the root-mean square difference between the calculation and measurement points in the penumbra region. The aggregate of error values for all the collimators at all the depths was plotted against the effective source size. We fit a quadratic function to the source size vs. error plot and determined the optimal source size for all collimator sizes combined, and for each collimator size separately. Since a single value for the source size is needed for the TPS we used the value that minimized the error for the aggregate set of data for the collimator sizes that are clinically relevant. In this case we included collimator sizes of 10-60mm for the variable aperture collimator (Iris).

Results: For the combination of all clinically relevant collimator sizes (10-60 mm), we find an optimal source size of 2.52 mm. The input is rounded to the nearest 0.1 mm so we used 2.5 mm for the final source size. The result for each collimator size separately are listed:

Collimator [mm], Optimal Source size [mm]: 5*,1.40; 7.5*,2.82; 10,2.68; 12.5,2.68; 15,2.57; 20,2.40; 25,2.32; 30,2.40, 35,2.49; 40,2.65; 50,2.69; 60,2.88 *not used clinically or in the optimal

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source size fit.

We found the effective source size for the 5 mm collimator was significantly lower than for the other collimator sizes. This is likely due to occlusion of the source by the collimator resulting in a smaller effective source size.

Conclusions: We report on a method to determine the optimal source size for a MC model. This method could potentially be automated in the TPS to reduce the amount of time and effort required by the user. At the current time this approach can be implemented by the user during commissioning to determine the optimal effective source size for a given system. The user will have to compute profiles for at least three different effective source sizes to generate error values that can be fit with a quadratic function.